Evolution of the Oxidation State of the Earth's Mantle: Challenges of High Pressure Quenching

L.R. DANIELSON1*, K. RIGHTER2, L. KELLER2, R. CHRISTOFFERSEN1, Z. RAHMAN1

1 Jacobs Technology, NASA-JSC, Houston, TX (lisa.r.danielson@nasa.gov*, roy.chrisstoffernsen-1@nasa.gov, zia.rahman-1@nasa.gov)

2 NASA-JSC, Houston, TX 77058 (kevin.righter-1@nasa.gov, lindsay.p.keller@nasa.gov)

The oxidation state of the Earth's mantle during formation remains an unresolved question, whether it was constant throughout planetary accretion [1], transitioned from reduced to oxidized [2,3,4], or from oxidized to reduced [1,5]. We investigate the stability of Fe^{3+} at depth, in order to constrain processes (water, late accretion, dissociation of FeO) which may reduce or oxidize the Earth's mantle.

Experiments of more mafic compositions and at higher pressures commonly form a polyphase quench intergrowth composed primarily of pyroxenes, with interstitial glass which hosts nearly all of the more volatile minor elements.

In our previous experiments on shergottite compositions, variable fO_2, T, and P <4 GPa, Fe^{3+}/TotFe decreased slightly with increasing P, similar to terrestrial basalt [6,7,8]. For oxidizing experiments < 7GPa, Fe^{3+}/TotFe decreased as well [9], but it's unclear from previous modelling whether the deeper mantle could retain significant Fe^{3+} [1,10]. Our current experiments expand our pressure range deeper into the Earth's mantle and focus on compositions and conditions relevant to the early Earth. Experiments with Knippa basalt as the starting composition were conducted at 1-8 GPa and 1800 °C, using a molybdenum capsule to set the fO_2 near IW, by buffering with Mo-MoO_3. TEM and EELS analyses revealed the run products from 7-8 GPa quenched to polycrystalline phases, with the major phase pyroxene containing approximately equal $Fe^{3+/2+}$.

A number of different approaches have been employed to produce glassy samples that can be measured by EELS and XANES. A more intermediate andesite was used in one experiment, and decompression during quenching was attempted after [11], but both resulted in a finer grained polyphase texture. Experiments are currently underway to test different capsule materials may affect quench texture. A preliminary experiment using liquid nitrogen to greatly enhance the rate of cooling of the assembly has also been attempted and this technique will be refined in further experiments.

[1]Righter and Ghiorso, 2012; [2]Rubie et al., 2011; [3]Wood et al., 2006; [4]Wänke and Dreibus, 1988; [5]Siebert et al., 2013; [6] Righter et al., 2013; [7] O'Neill, et al., 2006; [8] Kress and Carmichael, 1991; [9] Zhang et al., 2013; [10] Hirschmann, 2012 [11] Elkins et al., 2000.